**Supplementary Material**

***S 1. Method***

***S 1.1 Preparation of surimi gels***

After thawing at 4 °C overnight, surimi was cut into small pieces. Salts (2.5 g/100 g) were added to surimi and chopped at a speed of 2,100 rpm for 2 min in a Stephan vertical vacuum cutter (Model UM 5; Stephan Machinery Co., Hameln, Germany). Subsequently, different pre-emulsified safflower seed oils were added to surimi, and the final moisture content was adjusted to 80% with ice water, and chopped at the speed of 2,100 rpm for 3 min. The final content of safflower seed oil in surimi were 1, 2, 3, 4, and 5 mL per 100 g of surimi, respectively. During chopping, water was used as the cooling medium to maintain the sample temperature below 8 °C. After eliminating the air pockets, surimi was poured into a plastic casing (diameter, 2.5 cm) and both ends were sealed. Finally, the samples were incubated at 40 °C for 30  min, and then in a water bath at 90 °C for 20 min [2], [13]. Then samples were immediately placed in ice water and stored at 4  °C. Surimi gel without pre-emulsified safflower seed oil was used as the control.

***S 1.2. Water-holding capacity (WHC)***

Samples were chopped into bite-sized pieces and weighed accurately (*M*1). Then samples were wrapped with two filter papers and centrifuged (J-26sxp; Avanti, Beckman, USA) at 10,000 rpm for 10 min. After centrifugation, samples were weighed again (*M*2). The WHC was calculated following equation [2] (2):

 （2）

***S 1.3. Cooking loss rate (CLR)***

Samples were cut into small cylinders and weighed accurately (*G*1). Subsequently, the samples were sealed with a cooking bag and water bath at 90 °C for 20 min. After cooking, the liquid on the gel surface was dried with filter paper and weighed again (*G*2). The CLR was calculated following equation [21] (3):

 （3）

***S 2. Results***



Fig. A.1 Effects of safflower seed oil on water-holding capacity and cooking loss rate of the *Nemipterus virgatus* surimi gel.

Table A1 Effect of pre-emulsified safflower seed oil on volatile compound and content of the

*N. virgatus* surimi gel (μg/kg Gel)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Retent time (min)** | **Volatile compounds** | **Identification method** | **RI** | **Control** | **Safflower seed oil content (mL/100 g surimi)** | | | | |
| **1** | **2** | **3** | **4** | **5** |
| 3.449 | Hexanal | MS |  | 5.59±0.59d | 15.37±0.61c | 15.85±0.53c | 19.35±1.80b | 20.29±0.30b | 26.34±0.66a |
| 5.335 | 1-Hexanol | MS |  | 0.65±0.06d | 1.18±0.13c | 1.44±0.15b | 1.89±0.05a | 1.88±0.06a | 1.89±0.04a |
| 6.023 | 2-Heptanone | MS |  | 0.60±0.06d | 1.62±0.14c | 1.67±0.04c | 1.92±0.08b | 2.34±0.06a | 2.38±0.05a |
| 6.472 | Heptanal | MS |  | — | — | — | — | 8.87±0.37a | 8.79±0.31a |
| 7.531 | Thiazole, 4,5-dimethyl- | MS |  | — | — | — | — | 0.05±0.02a | 0.05±0.02a |
| 8.568 | Benzaldehyde | MS |  | 0.76±0.05e | 1.34±0.06d | 1.83±0.06c | 2.56±0.58b | 2.89±0.06ab | 3.09±0.05a |
| 9.115 | 2-Hexene, 3,5,5-trimethyl- | MS, RI | 972 | — | 4.71±0.40a | 4.61±0.46a | 4.62±0.24a | 4.64±0.20a | 4.69±0.27a |
| 9.396 | 1-Octen-3-ol | MS, RI | 1001 | 4.71±0.58c | 6.29±0.60b | 6.52±0.76b | 7.98±0.67a | 8.50±0.29a | 8.81±0.31a |
| 9.549 | 2,5-Octanedione | MS, RI | 1006 | 5.17±0.57c | 6.42±0.31b | 7.34±1.13ab | 6.68±0.42b | 8.24±0.14a | 8.22±0.09a |
| 10.231 | Octanal | MS, RI | 1029 | 2.57±0.25c | 3.27±0.15b | 3.12±0.30b | 3.26±0.19b | 4.15±0.11a | 4.16±0.21a |
| 11.169 | 1-Hexanol, 2-ethyl- | MS, RI | 1061 | 2.34±0.37a | 2.28±0.12a | 2.11±0.04a | 2.13±0.19a | 1.46±0.07b | 1.75±0.14b |
| 11.408 | 4-Ethylcyclohexanol | MS, RI | 1069 | — | — | — | 0.42±0.07a | 0.27±0.02b | 0.27±0.02b |
| 12.168 | Decane, 1,1'-oxybis- | MS |  | — | 0.29±0.03ab | 0.26±0.01b | 0.25±0.06b | — | 0.33±0.03a |
| 12.214 | Trichloroacetic acid, decyl ester | MS |  | — | — | — | 0.35±0.03a | — | — |
| 12.564 | 2-Octen-1-ol, (E)- | MS, RI | 1108 | 0.36±0.05c | 0.72±0.02b | 1.35±0.30a | 1.39±0.16a | 1.51±0.05a | 1.41±0.05a |
| 12.635 | 3-Cyclohexene-1-ethanol | MS, RI | 1110 | 1.55±0.15a | — | — | — | — | — |
| 13.002 | 4-Hexen-1-ol, acetate | MS, RI | 1123 | 0.46±0.03c | — | 0.39±0.10c | 1.54±0.34b | 1.98±0.06a | 1.98±0.06a |
| 13.371 | 2-Nonanone | MS, RI | 1086 | 1.60±0.25a | 1.23±0.12a | 0.72±0.14c | 0.63±0.08cd | 0.42±0.03de | 0.36±0.02e |
| 13.420 | 1-Nonen-4-ol | MS, RI | 1088 | — | — | — | 1.21±0.04a | — | — |
| 13.738 | Undecane | MS, RI | 1099 | 0.64±0.06d | 0.86±0.03c | 1.10±0.08b | 0.88±0.03c | 1.77±0.02a | 1.72±0.01a |
| 13.835 | Nonanal | MS, RI | 1099 | — | 7.51±0.38a | 7.02±0.27ab | 7.76±0.70a | 5.35±0.11c | 6.23±0.71b |
| 14.008 | Phenylethyl Alcohol | MS, RI | 1157 | 1.06±0.13d | 1.37±0.10cd | 2.13±0.49b | 1.56±0.10c | 2.28±0.12b | 2.78±0.18a |
| 14.171 | 6-Tridecen-4-yne, (Z)- | MS, RI | 1119 | 1.02±0.11ab | 1.18±0.20a | 1.23±0.33a | 0.84±0.05b | 0.53±0.05c | — |
| 14.684 | 1-Hexadecanol | MS, RI | 1021 | 0.04±0.01a | — | — | — | — | — |
| 15.706 | 2-Nonenal, (E)- | MS, RI | 1149 | 0.12±0.02d | 0.14±0.01d | 0.14±0.02cd | 0.22±0.03a | 0.18±0.01bc | 0.19±0.01ab |
| 15.729 | Benzaldehyde, 4-ethyl- | MS, RI | 1150 | 0.16±0.03a | 0.14±0.01ab | 0.10±0.03c | 0.13±0.01bc | — | — |
| 15.885 | 1,2-Propanedione, 1-phenyl- | MS, RI | 1154 | — | — | 0.10±0.05a | 0.06±0.03b | — | — |
| 16.111 | 13-Methyltetradecanal | MS, RI | 1159 | 0.71±0.04a | 0.19±0.03b | 0.18±0.04b | 0.15±0.02bc | 0.11±0.01c | 0.10±0.01c |
| 16.174 | 1-Nonanol | MS, RI | 1161 | — | 0.16±0.02a | 0.08±0.01c | 0.13±0.01b | — | — |
| 16.865 | 6-Dodecene, (E)- | MS, RI | 1184 | — | — | 0.12±0.01a | 0.09±0.02b | 0.13±0.02a | 0.13±0.02a |
| 16.976 | 2-Decanone | MS, RI | 1190 | 0.08±0.02b | 0.09±0.01b | 0.08±0.02b | 0.08±0.01b | 0.07±0.01b | 0.12±0.03a |
| 17.059 | 4-Decenal, (E)- | MS, RI | 1192 | — | 0.19±0.02a | — | — | — | — |
| 17.141 | 1,3-Cyclooctadiene | MS, RI | 1263 | 0.45±0.06c | 0.68±0.06b | 0.75±0.17b | 0.75±0.10b | 1.44±0.04a | 1.44±0.04a |
| 17.428 | Dodecane | MS, RI | 1199 | 0.37±0.03b | 0.44±0.02a | 0.43±0.05ab | 0.44±0.04a | 0.44±0.03a | 0.47±0.01a |
| 17.589 | Decanal | MS, RI | 1207 | 4.08±0.28a | 2.30±0.33b | 1.40±0.13c | 1.17±0.18cd | 0.76±0.05e | 0.87±0.09de |
| 19.302 | Caprolactam | MS |  | 0.14±0.02d | 0.50±0.05c | 0.47±0.03c | 0.65±0.08ab | 0.62±0.06b | 0.73±0.02a |
| 20.068 | 3-Dodecyne | MS, RI | 1269 | 0.99±0.09d | 1.24±0.12cd | 1.50±0.34bc | 1.60±0.07b | 1.94±0.09a | 2.10±0.14a |
| 20.078 | cis,cis-7,10,-Hexadecadienal | MS, RI | 1197 | — | — | — | — | 0.58±0.05a | — |
| 20.869 | Indole | MS, RI | 1389 | 0.19±0.04d | 0.23±0.01cd | 0.34±0.07bc | 0.24±0.02cd | 0.53±0.04a | 0.33±0.05ab |
| 21.077 | 2-Undecanone | MS, RI | 1297 | 0.69±0.08c | 0.79±0.08bc | 0.86±0.33bc | 0.67±0.05c | 1.00±0.12b | 1.34±0.03a |
| 21.462 | Tridecane | MS, RI | 1308 | 0.14±0.02b | 0.20±0.02b | 0.18±0.05b | 0.16±0.02b | 0.23±0.01a | 0.25±0.01a |
| 21.661 | Undecanal | MS, RI | 1313 | 0.34±0.04a | 0.14±0.01b | 0.14±0.02b | 0.15±0.02b | 0.09±0.01c | 0.10±0.01c |
| 22.266 | Dodecane, 4,6-dimethyl- | MS, RI | 1317 | 0.05±0.01c | 0.13±0.02a | 0.09±0.02b | 0.09±0.01b | 0.08±0.01b | 0.09±0.01b |
| 23.711 | 1,11-Dodecadiyne | MS, RI | 1365 | — | 0.21±0.03a | — | 0.18±0.03b | 0.16±0.01b | 0.15±0.01b |
| 24.081 | 2-Bromo dodecane | MS, RI | 1374 | — | — | — | 0.02±0.01a | 0.02±0.01a | 0.04±0.01a |
| 24.874 | 2-Pentadecen-4-yne, (Z)- | MS, RI | 1396 | 0.13±0.03a | 0.15±0.01a | 0.15±0.05a | 0.15±0.03a | 0.11±0.01a | 0.12±0.01a |
| 25.170 | Tetradecane | MS, RI | 1400 | 0.27±0.03c | 0.40±0.04bc | 0.39±0.15bc | 0.42±0.05b | 0.68±0.04a | 0.70±0.05a |
| 25.405 | Dodecanal | MS, RI | 1409 | 0.23±0.03a | 0.15±0.01b | 0.15±0.01b | 0.12±0.02c | 0.11±0.01c | 0.10±0.02c |
| 25.842 | 1H-Indene, octahydro-2,2,4,4,7,7-hexamethyl-, trans- | MS, RI | 1422 | 0.11±0.02a | 0.12±0.01a | 0.09±0.03a | 0.09±0.01a | 0.08±0.01a | 0.08±0.01a |
| 26.701 | 5,9-Undecadien-2-one, 6,10-dimethyl-, (E)- | MS, RI | 1439 | 0.55±0.03a | 0.19±0.02b | 0.17±0.06b | 0.22±0.07b | 0.17±0.01b | 0.15±0.03b |
| 27.130 | Decahydro-1,1,4a,5,6-pentamethylnaphthalene | MS, RI | 1457 | — | 0.10±0.02a | 0.09±0.02a | 0.09±0.01a | 0.06±0.02a | 0.07±0.02a |
| 27.254 | 2,6,10-Trimethyltridecane | MS, RI | 1431 | 0.09±0.01b | 0.12±0.01a | 0.11±0.03ab | 0.13±0.01a | 0.08±0.01b | 0.08±0.01b |
| 28.054 | 7-Pentadecyne | MS, RI | 1482 | — | 0.11±0.02b | 0.17±0.07a | 0.21±0.03a | 0.22±0.01a | 0.19±0.02a |
| 28.419 | 1-Eicosanol | MS |  | — | 0.08±0.01a | 0.09±0.04a | — | — | 0.06±0.01a |
| 28.429 | 1-Hexadecanol, 2-methyl- | MS, RI | 1468 | 0.05±0.01a | — | — | 0.06±0.01a | 0.05±0.01a | 0.04±0.01a |
| 28.729 | Pentadecane | MS, RI | 1500 | 1.51±0.31c | 1.92±0.27b | 1.70±0.71b | 2.01±0.04a | 2.37±0.13a | 2.33±0.07a |
| 29.023 | Tributyl phosphate | MS |  | 0.41±0.04a | 0.33±0.02a | 0.34±0.15a | 0.45±0.09a | 0.38±0.01a | 0.37±0.03a |
| 30.683 | 1,8,11-Heptadecatriene, (Z,Z)- | MS, RI | 1542 | — | — | 0.06±0.03b | 0.09±0.01a | — | — |
| 30.703 | 10(E),12(Z)-Conjugated linoleic acid | MS |  | — | — | — | — | 0.08±0.01a | 0.06±0.01a |
| 30.770 | 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)- | MS, RI | 1555 | — | 0.10±0.01a | — | — | 0.09±0.01a | 0.09±0.01a |
| 31.686 | 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate | MS, RI | 1576 | 0.32±0.04cd | 0.70±0.10a | 0.51±0.08b | 0.38±0.04c | 0.38±0.02c | 0.26±0.02d |
| 32.567 | Tetradecanal | MS, RI | 1609 | 0.12±0.02a | 0.13±0.03a | 0.12±0.04a | 0.13±0.01a | 0.06±0.01b | 0.07±0.01b |
| 32.870 | Phenol, 2,6-bis(1,1-dimethylethyl)-4-(1-methylpropyl)- | MS |  | 0.05±0.01a | 0.08±0.03a | 0.07±0.02a | 0.07±0.01a | 0.05±0.01a | 0.06±0.01a |
| 34.635 | 1,2-Oxathiane, 6-dodecyl-, 2,2-dioxide | MS, RI | 1672 | — | 0.07±0.01c | 0.07±0.02c | — | 0.43±0.04a | 0.30±0.03b |
| 35.420 | Hexadecane | MS, RI | 1609 | 0.18±0.02b | 0.25±0.03a | 0.24±0.02a | 0.26±0.02a | 0.20±0.01a | 0.22±0.01a |
| 35.548 | Pentadecane, 2,6,10,14-tetramethyl- | MS, RI | 1755 | 0.70±0.07b | — | — | 0.87±0.03a | — | — |
| 35.783 | 10-Octadecenal | MS, RI | 1844 | — | — | 0.09±0.01a | — | 0.07±0.01a | — |
| 35.790 | Tridecanal | MS, RI | 1670 | 0.12±0.01a | — | — | 0.12±0.01a | 0.09±0.01b | 0.09±0.01b |
| 38.370 | Heptadecane | MS, RI | 1773 | — | 0.03±0.01a | 0.03±0.02a | 0.03±0.01a | — | 0.03±0.02a |
| 38.817 | Hexadecanal | MS, RI | 1809 | 0.16±0.02b | 0.20±0.02a | 0.12±0.01c | 0.17±0.02b | — | 0.10±0.00c |
| 39.234 | 4,8,12-Tetradecatrienal, 5,9,13-trimethyl- | MS, RI | 1823 | — | 0.06±0.01a | — | — | 0.06±0.02a | — |
| 40.065 | 1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester | MS, RI | 1850 | — | 0.28±0.03c | 0.27±0.04c | 0.52±0.14b | 0.68±0.04a | 0.71±0.06a |
| 41.756 | 1-Heptadecanamine, N,N-dimethyl- | MS |  | — | — | — | — | — | 0.05±0.01a |
| 41.769 | Dimethyl palmitamine | MS |  | 0.04±0.01a | 0.06±0.02a | 0.06±0.01a | 0.05±0.01a | 0.04±0.01a | 0.04±0.01a |
| 43.002 | Dibutyl phthalate | MS, RI | 1945 | 0.25±0.03c | 0.29±0.02c | 0.45±0.17b | 0.46±0.08b | 0.63±0.04a | 0.65±0.05a |

Note: The data are expressed in the form of mean ± standard deviations (n=3). Different letters within the same row indicate significant differences (P < 0.05) between mean values, “—” means not detected.